



Non-monotonic group-size effect in repeated provision of public goods



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ABSTRACT

This paper analyzes the effect of a change in group size on incentives to contribute in repeated provision of pure public goods. We develop a model in which group members interact repeatedly, and might be temporarily unable to contribute to public goods production during some periods. We show that an increase in the group size generates two opposite effects – the standard free-riding effect that suppresses cooperation, and the novel large-scale effect that enhances cooperation. Our results indicate that the former effect dominates in relatively large groups while the latter dominates in relatively small groups. We, therefore, provide a rationale for a non-monotonic group-size effect that may explain previous empirical and experimental findings.

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1. Introduction

Private provision of public goods often involves repeated interactions among potential contributors. However, an individual might be temporarily unable to contribute to public goods production during some periods. For instance, a team is assigned a new task to solve every period, but an individual team member might lack expertise in solving some of the tasks or might be unavailable while overloaded with other tasks. Another example is review posting or file sharing in online communities. There too, users might have no information to post or no files to share, or may sometimes be busy with other things. In this paper, we develop a model in which group members might be temporarily unable to contribute to public goods production. We analyze repeated provision of pure public goods and focus on the effect of an increase in group size on individuals' incentives to cooperate, referred to as the group-size effect.

Existing experimental and empirical evidence on the group-size effect is mixed. For example, [Ledyard \(1995\)](#) reports that free-riding behavior increases with group size, while [Goeree et al. \(2002\)](#) find no clear group-size effect. In turn, [Zhang and Zhu \(2011\)](#) show that an exogenous reduction in group size lowers the average contribution levels of the remaining contributors at Chinese Wikipedia. The evidence of non-monotonic group-size effect is reported in experimental studies by [Isaac and Walker \(1988\)](#) and [Isaac et al. \(1994\)](#). In this paper, we shed some light on this mixed evidence because we uncover a non-monotonic relationship between group size and each individual's incentives to cooperate. In particular, for small groups, we find a positive effect of group size on average contributions, while for large groups, we find a negative effect.

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In our repeated game framework, group members have private information about their own abilities to contribute to public goods production every period, and independently choose whether to contribute or not. Moreover, they are purely consumption driven and gain no altruistic payoffs (such as moral satisfaction and the joy of giving) from making a contribution. Group members can condition their contribution decisions on whether the public good has been provided or not in the previous periods. While it is not surprising that repeated interactions can incentivize cooperation, the mechanism at work is novel for the public goods literature. Each member able to contribute faces the following trade-off. On the one hand, he has strong incentives to free-ride because contributing is costly and the public good might as well be provided by other able members. On the other hand, he might be unable to contribute in some future periods and will thus have to rely on contributions by his able peers. However, peers will contribute only if cooperation in the group has not broken down by then. Cooperation can be sustained in equilibrium if the group members are sufficiently patient.

Our main finding is related to the group-size effect. We show that for a range of parameter values, the incentives to cooperate increase with group size if the initial group size is relatively small but decrease with group size if the initial group size is relatively large. In short, the group-size effect is positive in small groups but negative in large groups. The intuition for this result is as follows. On the one hand, free-riding incentives strengthen as the group grows in size. Each member realizes that in a larger group, other members are more likely to contribute to the public goods provision and it is less likely that his own deviation breaks down cooperation. Therefore, an increase in the group size has a negative effect on incentives to cooperate. On the other hand, there is also a positive effect since the continuation value of cooperation increases with group size. We call this the “large-scale effect”. Intuitively, a larger group will have more members able to contribute to public goods production in the future periods. Thus, each member expects a higher payoff in the future periods during which he becomes unable to contribute, and so has extra incentives to sustain cooperation during periods during which he is able to contribute.

The remainder of the paper is organized as follows. The next section describes the related literature. [Section 3](#) outlines the baseline model. [Section 4](#) characterizes the equilibrium. [Section 5](#) presents the group-size effect analysis, with extensions described in [Section 6](#). Finally, [Section 7](#) concludes.

2. Related literature

Our paper contributes to the literature on the voluntary provision of pure public goods. Two types of contribution technology have been studied in this literature. The best-shot models (e.g., [Hirshleifer, 1983](#); [Cornes, 1993](#); [Harrington, 2001](#); [Barbieri and Malueg, 2014](#)) assume that the maximum individual contribution determines the public good level. Models with cumulative contributions (e.g., [Olson, 1965](#); [Chamberlin, 1974](#); [Bergstrom et al., 1986](#); [Andreoni, 1988](#)) assume that the sum of the individual contributions determines the public good level. In most of these studies, the free-riding effect drives individuals' incentives to contribute and the marginal return from contributions decreases with group size.¹ Our model contributes to this literature by showing that in a repeated context, the marginal benefit from contributing can be positive, and therefore, the group-size effect can be non-monotonic, both under non-cumulative and cumulative contribution technologies.²

This paper is also related to the literature on dynamic free-rider problems, which focuses mainly on durable contribution settings.³ To the best of our knowledge, [Pecorino \(1999\)](#) published the only study of a repeated setting with non-durable contributions. He assumes perfect monitoring, able agents, large groups, and grim-trigger strategies (i.e., trigger strategies under which the punishment period goes to infinity). In his setting, cooperation can be sustained even in an infinitely-large group. In contrast, we consider imperfect monitoring, temporarily disabled individuals, finite groups, and optimal punishment. We can then compare incentives to cooperate in finite groups of different sizes and explicitly identify the group-size effect.

The large-scale effect we find is related to the positive “encouragement” effect described in [Yildirim \(2006\)](#) and [Georgiadis \(2015\)](#). They analyze dynamic voluntary contributions to the gradual completion of a project. In their setting, an increase in group size implies faster completion of the project, which increases members' continuation value of cooperation and so strengthens their incentives to cooperate. While their “encouragement” effect works in favor of cooperation by shortening the project duration, our large-scale effect improves cooperation by increasing members' expected payoff in every future period.

¹ The notable exceptions are [Chamberlin \(1974\)](#) and [McGuire \(1974\)](#), in which a positive group-size effect arises due to the positive income effect on the public good provision. The positive group-size effect is also reported in the literature on impure public good provision, which assumes that agents gain certain private benefits or a warm glow (such as moral satisfaction and the joy of giving) from their own contributions (see [Cornes and Sandler, 1984](#); [Bergstrom et al., 1986](#); [Steinberg, 1987](#); [Andreoni, 1989, 1990](#), among many others). These private benefits are assumed to increase with the number of recipients, which generates the positive group-size effect. In this paper, however, we assume no private benefits from contributing.

² [Xu \(2001\)](#) and [Barbieri and Malueg \(2014\)](#) show that an increase in group size may increase the total amount of public goods provided in the best-shot models with private information. Our results differ in that the average (and not just total) contributions can increase with group size.

³ The classical references include [Fershtman and Nitzan \(1991\)](#), who study a dynamic public goods problem; [Marx and Matthews \(2000\)](#), who consider a dynamic fundraising environment; [Lockwood and Thomas \(2002\)](#), who analyze a repeated Prisoner's Dilemma with irreversible contributions; and many others. These studies assume that individual contributions accumulate over time and thus are (partially) durable. In this paper, we abstract from this intertemporal link and focus on environments with non-durable contributions, which are quite common in real-world practice.

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